HIGH EFFICIENCY RESIDENTIAL
CONDENSING GAS FURNACE
FIELD EVALUATION
INTERIM REPORT

A Housing Energy Management Program Report

Energy
Ontario

HIGH EFFICIENCY RESIDENTIAL CONDENSING GAS FURNACE FIELD EVALUATION INTERIM REPORT

UNDERTAKEN JOINTLY BY THE ONTARIO MINISTRIES OF MUNICIPAL AFFAIRS AND HOUSING AND ENERGY AND THE CONSUMERS' GAS COMPANY LTD. UNDER THE HOUSING ENERGY MANAGEMENT PROGRAM (H.E.M.P.)

PREPARED FOR
ONTARIO MINISTRY OF MUNICIPAL AFFAIRS AND HOUSING
TECHNICAL SERVICES DIVISION
RESEARCH AND DEVELOPMENT SECTION
BY
THE CONSUMERS' GAS COMPANY LTD.

MARCH 1983

ISBN # 0-7743-8177-9

TABLE OF CONTENTS

	Page
1.0 SUMMARY	1
2.0 INTRODUCTION	2
3.0 OBJECTIVE	3
4.0 EVALUATION PHILOSOPHY	4
5.0 ANALYSIS OF DATA	6
6.0 NORMAL INSTALLATION COSTS	11
7.0 INTERIM COMMENTS	12
8.0 INTERIM CONCLUSIONS	14
REFERENCES	15
APPENDICES: MONTHLY COST PROJECTIONS	16

1.0 SUMMARY

This report covers the analyses of three months of data collected over the 1981/82 heating season from each of two high efficiency gas furnace test installations located in the greater Metropolitan Toronto area.

From the data collected, observed seasonal efficiencies of 85.1% and 83.9% are indicated for the Scarborough and Markham sites respectively.

From the spread of the data, it is apparent that a longer test period would produce more conclusive and statistically significant results.

"Normal" energy costs were projected from the data. Operating costs using natural gas fuel were $388 at the Scarborough site and $563 at Markham, showing savings over electric heating of $219 and $361 respectively for the period under test.

2.0 INTRODUCTION

Two models of a new high efficiency condensing gas furnace are under field evaluation in two differently sized and styled homes in the greater Toronto area.

This interim report analyses the data collected to date and presents calculated seasonal efficiencies, projected energy costs and potential savings.

Data collection at both sites commenced in early February 1982 and continued through the remainder of the heating season.

Normal installation costs were estimated for each test site and are included in the report.

An installation report entitled, "High Efficiency Residential Condensing Gas Furnace Field Evaluation' was published in April 1982.

3.0 OBJECTIVE

The objective of this programme is to determine the seasonal efficiency functional performance and site operating costs of a new design of Canadian made condensing gas furnace.

Steady state efficiencies have not been assessed in this test.

4.0 EVALUATION PHILOSOPHY

The high efficiency gas furnaces were monitored against electric furnaces at each site. Since the electric furnace can be assumed to be 100% energy efficient at site, a heating load comparison can be used to assign a seasonal efficiency to the gas furnaces.

At each site daily energy consumption readings were taken and the outside temperature was recorded. A mean daily outside temperature was obtained for each daily reading period by intergrating the outside temperature recordings.

When the daily energy consumption (Rate of heat loss) is plotted against the outside temperature, the expected curve is linear and a standard regression can be used to determine slope (Rate of daily energy consumption per degree) and intercept T_B (Balance point temperature).

From these best fit curves daily energy consumption can be predicted for a given mean temperature. Weekly, monthly, and annual consumptions are obtained by multiplying the daily rate by the number of days required.

Since neither the gas or electric furnaces under test change the heating requirements of the house, a common balance point temperature is expected at each dwelling. The common point can be estimated from the data and the regressed lines forced through this point.

Seasonal efficiency calculations are based on the assumption of a common balance point. The thermostat is used and switch over is conducted daily to avoid the effects of trends in living habits, weather, and other demographic factors outwith the control of the recorder on the balance point temperature. Thermostat anticipator settings were not considered to have a significant effect on the performance over the period under test.

With a common balance point, the seasonal efficiencies can be simply calculated from the differences in slope at each site. The formula, $N = \frac{K_1}{K_2} \times 100$ is used, where N is the percent energy efficiency of the gas furnace and K_1 and K_2 are the consumption rates per degree for the gas and electric furnaces.

The high efficiency gas furnaces can be compared to conventional electric units by seasonal efficiencies. A percent reduction in gas use and a proportional cost saving can be calculated.

5.0 ANALYSIS OF DATA

Data was collected over approximately the last three months of the heating season. The Scarborough site collected 80 days of useable data; the Markham site 65 days.

Outside temperature was recorded on site and the mean outside temperature calculated by intergrating the chart recordings. However, during the first 5 weeks, Bloor Street weather station data was used in calculations for the Scarborough site since the on site recorder was being repaired and recalibrated. While the temperatures experienced at the Bloor Street station are very similar, the reported daily mean temperature is calculated differently. Instead of being weighted over the whole day, it is a straight average of the daily high and low temperatures. On sunny days where a narrow temperature peak occurs, this introduces an added variability since heat is called for during most of the day when it is predominately cold. At this stage in the field evaluation it is not known whether this has a significant effect on the results and computations.

Each test furnace was operated on alternate days, so that a comparison could be made against the electric furnace as a hard reference.

Daily energy consumption was plotted against daily mean outside temperature at each site. Data points are shown in Figures 1 and 2, Pages 7 and 8. A linear regression was performed and best fit curves (shown dotted) were fitted to the data.

FIGURE 1

SCARBOROUGH CONSUMPTION DATA

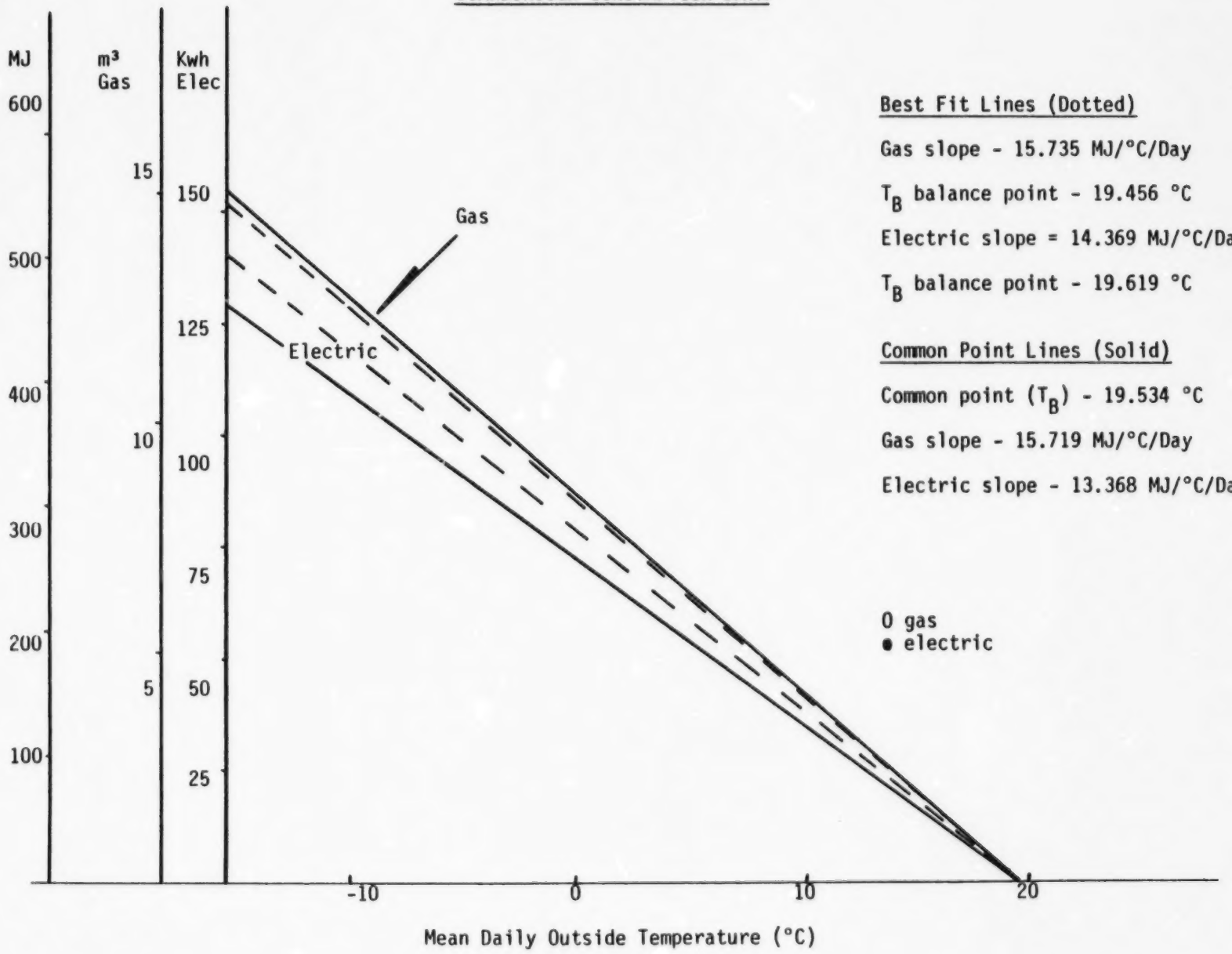
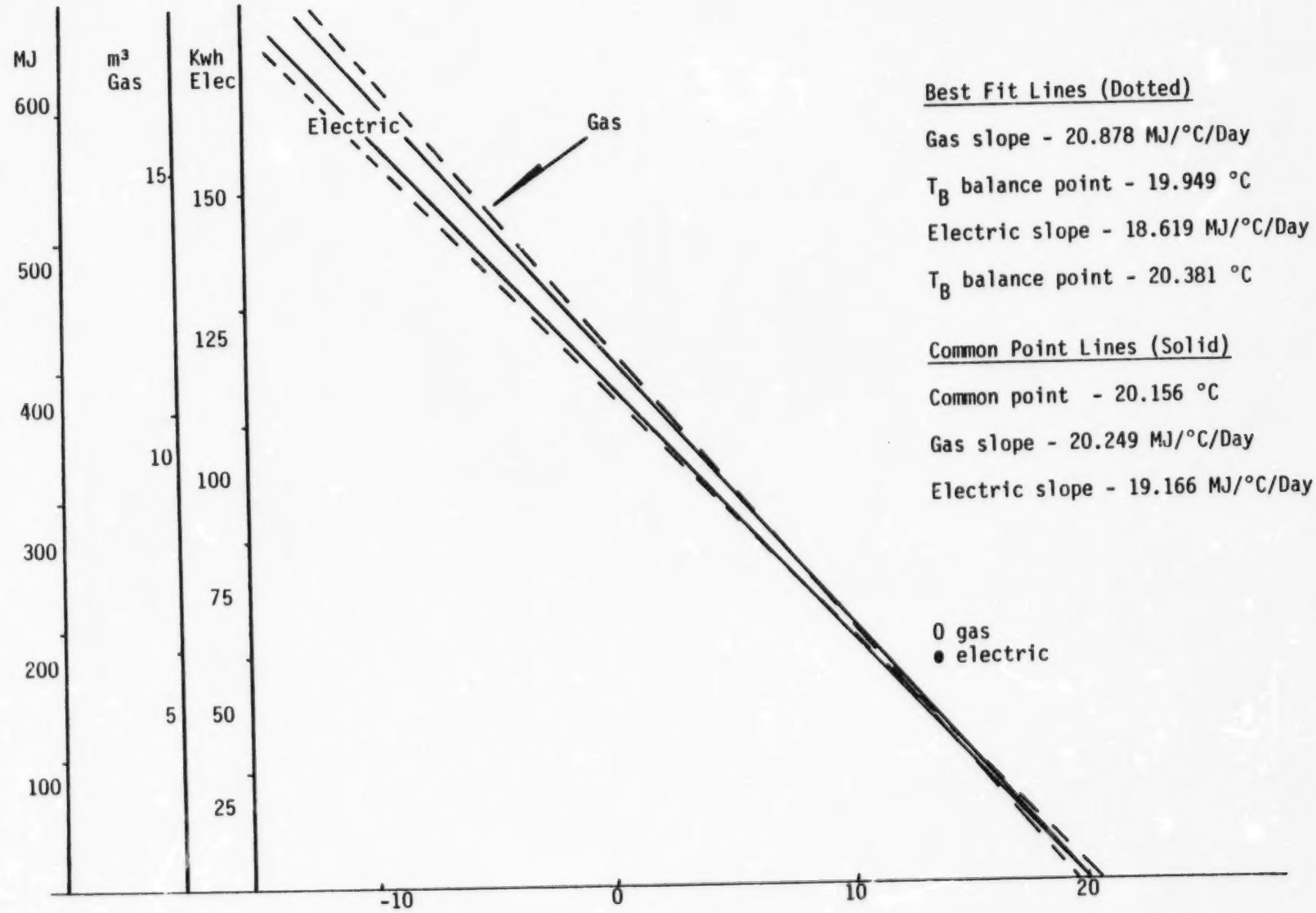


FIGURE 2

MARKHAM CONSUMPTION DATA



At the Scarborough site, balance point temperatures indicated by the best fit curves were 19.46°C and 19.62°C for gas and electric heating respectively, which is very close and consistent. No statistical evidence was found against the hypothesis that the balance point temperature in this dwelling remained the same regardless of whether the high efficiency gas or electric heating was used. The balance point temperature was estimated from the data as 19.53°C.

On the assumption of a common balance point at the Scarborough site, the data was regressed again and the lines forced through this point (shown as solid on Figure 1). Slopes obtained were 15.72 MJ/°C/Day and 13.37 MF/°C/Day respectively for gas and electric. Comparison of these slopes lead to a calculated seasonal efficiency.

For the Scarborough test site the seasonal efficiency calculated on this basis was 85.1% with a 95% confidence interval of 80.6% to 90.0% efficiency. That is, there is reasonable statistical evidence that the actual seasonal efficiency of this furnace was in this 10% range with the most likely actual efficiency of 85.1%.

In Markham, the data was more variable and therefore cannot be as conclusive. This could be due to a number of demographic factors, changes in living habits or insufficient data for statistical significance.

Data from the Markham site was treated in the same way as for the Scarborough site. Again, no evidence was found against the hypothesis

that the balance point temperature remained unchanged. A common point was estimated at 20.2°C and the regressed lines forced through this point.

From the comparison of the slopes of these lines, the gas furnace on site was indicated to be 94.3% efficient, however due to the variability of the data, the conclusion that could be statistically supported was that the unit was at least 83.9% efficient and this figure is the one quoted in this interim report, although the 94.3% is close to the manufacturers claim.

Steady state efficiencies were not recorded as the manufacturers figure of 93% has been accepted provisionally for this interim report.

Table 1 page 17 shows the summary of the projected costs for the 1981/82 heating season computed from the actual data.

Tables 2 and 4 on pages 18 and 20 in the Appendix show costs projected on actual weather data for the 1981/82 heating season. The 1981/82 heating season was a little colder than normal.

Tables 3 and 5 on pages 19 and 21 in the Appendix show costs projected for "normal" weather year.

Projected costs were calculated on a rate of 20.8¢/m^3 for natural gas and 3.7¢/kW for electricity. These rates are blended tail end rates and are reasonable for a household in the Metro Area, for the period covering the test.

6.0 NORMAL INSTALLATION COSTS

Although each test site was specially installed complete with monitoring instrumentation and recording instruments, the Contractors were asked to estimate homeowner costs for a standard installation of (a) a high efficiency condensing furnace; (b) a conventional gas furnace, and (c) an electric furnace, individually, at each site, these estimates are quoted below:

SITE	FURNACE TYPE		
	Condensing Gas	Conventional Gas	Conventional Electric
Scarborough	$3,300	$1,500	$1,500
Markham	$3,500	$1,700	$1,700

It should be recognized that installation costs vary widely from site to site.

The cost for the conventional gas furnace installation does not include the additional cost of a chimney liner which, if required, would cost approximately $400. The installation cost for the conventional electric furnace excludes the cost of the upgrading of the existing residential electrical service. Should a 200 amp service be required, an extra installation cost of approximately $1,000 would be required.

7.0 INTERIM COMMENTS ON THE OPERATION OF THE FURNACES

Both furnaces operated well over the short period of the test, during the 1981/82 heating season, maintaining the home temperature desired. The installation at the Scarborough site required no service calls, but an external fresh air inlet was connected to the return air plenum to relieve a perceived stale air condition. At the Markham site several start-up difficulties were experienced which required the replacement of two components. However, at both sites maintenance costs to date have been no different than those expected for a conventional gas furnace.

A partial analysis of the flue gases at both sites was conducted and showed:

	SITE	
Component	Scarborough	Markham
Outside temp. (°C)	1	1
Indoor temp (°C)	20	19
Flue Gas temp (°C)	25	44
Carbon Monoxide (ppm)	10	10
Oxides of Nitrogen (ppm)	15	35
Oxygen (%)	12.9	9.8

Condensate samples were taken with the gas furnaces operating in the steady state condition and after the condensate treatment canisters; the analysis of the treated condensate showed that a P.H. of 9.40 was recorded at the Scarborough site and a P.H. of 9.50 was measured at the Markham site, flow rate of the condensate whilst varying widely averaged out at approximately 0.51 l/hr.

Over the next heating season the analysis will be improved four ways.

1. Consumption data collected over a wider range of temperatures will further define the extent of the regressed lines giving a better basis for projected consumptions and costs. Data collected in the colder months will substantiate the upper end of the heat loss curves and give a wider basis for conclusions.

2. A large sample size, i.e. increased number of points, will increase accuracy in determining the rate of heat loss for a given outside temperature.

3. With a larger sample size the balance point temperature can be more accurately determined, leading to a better prediction of energy usages and associated costs.

4. The assumption of a common balance point for each dwelling can be more fully tested with a larger sample size. Determining the accuracy of this assumption will lead to a more comprehensive analysis.

5. At the Scarborough site, all occupants of the house work during the day and a setback thermostat is used. Over the next heating season, the weekends, when everyone is home, will be examined separately to determine the variation if any, in gas consumption.

8.0 INTERIM CONCLUSIONS

1. This high efficiency condensing furnace is less expensive to operate than an equivalent conventional electric furnace.

2. The appliance installed at the Markham test site showed an 83.9% seasonal efficiency during the period of the test.

3. The furnace installed at Scarborough indicated a seasonal efficiency of 85.1%.

4. The appliance presents no special service or maintenance difficulties.

REFERENCES

Canadian Climate Normals; Ontario, Environment Canada

@ 1980 Environment Canada

SI Units and Conversion Factors for the Canadian Gas Industry

@ June 1981, Canadian Gas Association

Statistical Methods, Seventh Edition, Snedcor and Cochran

@ 1980 Iowa State University Press

APPENDICES

PROJECTED MONTHLY COSTS

TABLE 1

COMPUTED COST SUMMARY FOR BOTH SITES

SITE	OPERATING MODE	PROJECTED COSTS ($)	
		81/82 Season	Normal
Scarborough	Gas	417.25	387.92
	Electricity	653.12	607.36
	Savings	235.88	219.44
Markham	Gas	577.62	562.85
	Electricity	947.76	923.53
	Savings	307.14	360.68

TABLE 2

1981/82 SEASONAL ENERGY COSTS - MARKHAM

MONTH	MEAN MONTHLY TEMP. (°C)	ENERGY CONSUMPTION/MONTH		COST/MONTH		Savings ($)
		Gas Furnace (m^3)	Electric Furnace (Kwh)	Gas Furnace ($)	Electric Furnace ($)	
July	21	0	0	-	-	-
August	20	3	26	0.62	0.96	0.34
September	14	104	956	21.63	35.37	13.74
October	7	229	2110	47.63	78.07	30.44
November	3	289	2663	60.11	98.53	38.43
December	-3	402	3713	83.62	137.38	53.77
January	-10	524	4836	108.99	178.93	69.94
February	-7	426	3933	88.61	145.52	56.91
March	-2	385	3553	80.08	131.46	51.38
April	5	255	2352	53.04	87.02	33.98
May	15	90	827	18.72	30.60	11.88
June	16	70	646	14.56	23.90	9.34
TOTAL		2777	25615	577.61	947.74	370.15

Rates Gas: 20.8¢/m^3
Electric: 3.7¢/Kwh

TABLE 3

NORMAL SEASONAL ENERGY COSTS - MARKHAM

MONTH	NORMAL MEAN MONTHLY TEMP. (°C)	ENERGY CONSUMPTION/MONTH		COST/MONTH		Savings ($)
		Gas Furnace (m^3)	Electric Furnace (Kwh)	Gas Furnace ($)	Electric Furnace ($)	
July	20.1	1	10	0.21	0.37	0.16
August	19.1	18	170	3.74	6.29	2.55
September	15.0	87	801	18.10	29.64	11.54
October	8.8	197	1822	40.98	67.41	26.44
November	3.0	289	2663	60.11	98.53	38.42
December	-3.9	418	3858	86.94	142.75	55.80
January	-7.1	474	4371	98.59	161.73	63.14
February	-6.6	420	3875	87.36	143.38	56.02
March	-1.4	375	3457	78.00	127.91	49.91
April	5.8	242	2228	50.34	82.44	32.10
May	12.1	140	1292	29.12	47.80	18.68
June	17.5	45	413	9.36	15.28	5.92
TOTAL		2706	24960	562.85	923.53	360.68

Rates Gas: 20.8¢/m^3
Electric: 3.7¢/Kwh

TABLE 4

1981/82 SEASONAL ENERGY COSTS - SCARBOROUGH

MONTH	MEAN MONTHLY TEMP. (°C)	ENERGY CONSUMPTION/MONTH		COST/MONTH		Savings ($)
		Gas Furnace (m^3)	Electric Furnace (Kwh)	Gas Furnace ($)	Electric Furnace ($)	
July	21	0	0	-	-	-
August	20	0	0	-	-	-
September	14	70	617	14.56	22.83	8.27
October	7	164	1443	34.11	53.39	19.28
November	3	209	1842	43.47	68.15	24.68
December	-3	295	2594	61.36	95.98	34.62
January	-10	386	3400	80.29	125.80	45.51
February	-7	314	2759	65.31	102.08	36.77
March	-2	282	2479	58.66	31.72	33.07
April	5	184	1619	38.27	59.90	21.63
May	15	57	505	11.86	18.69	6.83
June	16	45	394	9.36	14.58	5.22
TOTAL		2006	17652	417.25	653.12	235.88

Rates Gas: 20.8¢/m^3
Electric: 3.7¢/Kwh

TABLE 5

NORMAL SEASONAL ENERGY COSTS - SCARBOROUGH

MONTH	NORMAL MEAN MONTHLY TEMP. (°C)	ENERGY CONSUMPTION/MONTH		COST/MONTH		Savings ($)
		Gas Furnace (m^3)	Electric Furnace (Kwh)	Gas Furnace ($)	Electric Furnace ($)	
July	21.0	0	0	-	-	-
August	20.1	0	0	-	-	0
September	15.9	46	405	9.57	14.99	5.42
October	9.3	134	1178	27.87	43.59	15.71
November	3.5	203	1786	42.22	66.08	23.86
December	-3.4	300	2640	62.40	97.68	35.28
January	-6.7	343	3020	71.34	111.74	40.40
February	-5.6	297	2613	61.78	96.68	34.91
March	-0.8	266	2341	55.33	86.62	31.29
April	6.4	166	1463	34.53	54.13	19.60
May	12.6	91	798	18.93	29.53	10.60
June	18.0	19	171	3.95	6.33	2.38
TOTAL		1865	16415	387.92	607.37	219.45

Rates Gas: 20.8¢/m^3
Electric: 3.7¢/Kwh